Senior Thesis

Composting of Sewage Sludge

by

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ABSTRACT

Sewage sludge disposal presents an enormous problem to municipalities. A very effective way of dealing with this problem is to compost the sludge. Composting is a biological process that will reduce the waste product of sewage sludge to a useful resource in a way that is harmless to the environment. Composting is also less expensive than landfilling, incinerating, or dumping the sewage sludge into the ocean.

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) estimated in 1989 that approximately 15,300 publicly owned treatment works (POTWs) generated 7.7 million dry metric tons of sewage sludge, or biosolids, each year. This is equivalent to about 29 kg(64 lbs) dry solids annually for each individual in the U.S. The sewage sludge generated each year was estimated to fill 186,000 railroad cars, enough to span half of the country (U.S. EPA, 1989). The volume of sludge is expected to double by the year 2000 due to more efficient treatment plants, stricter wastewater treatment requirements, and population growth. Disposal of this volume of material poses problems for municipalities and several techniques are used, including composting. Compared to other disposal methods of sewage sludge such as incinerating, landfilling, or ocean dumping, composting is generally less expensive and better for the environment; it also produces a useable end product.

At this point in the introduction, it is appropriate to provide definitions for some of the common terms in composting.

Sewage sludge (biosolids)- the organic and inorganic matter removed from wastewater at sewage treatment plants.

Composting- "The biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land."(Haug, 1993)

Compost- "An organic soil conditioner that has been stabilized to a humus-like product, that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and stored without nuisance, and that is beneficial to the growth of plants."(Haug, 1993)

Biological Review

The microbes that make the process of composting occur belong to Kingdom Protista. Kingdom Protista includes algae, fungi, protozoa, virus particles, and bacteria. Microbes can be classified into different metabolic types based on the way carbon and energy sources are used by the cell (Campbell, 1992). Autotrophs use carbon dioxide as a source of cell carbon. Heterotrophs use the carbon of organic molecules. Lithotrophs use the energy of inorganic chemical reactions, while organotrophs use the energy of organic chemical reactions. Phototrophs obtain energy from light. Algae are examples protist phototrophs. The important composting microbes, bacteria and fungi, are organoheterotrophs using organic compounds as a source of energy and cell carbon.

Bacteria are the smallest living organisms known. They are typically unicellular and have a procaryotic cell structure. In procaryotes there is not a true nucleus. Fungi are divided into molds and yeasts. All molds have aerobic cellular respiration while yeasts can respire both aerobically and anaerobically. Molds and yeasts both have a eucaryotic cell structure (a true nucleus) and are organoheterotrophs (Campbell, 1992).

Microbial nutrients are the energy sources and building blocks used by microbes for maintaining and building their structure and organization (Poincelot, 1977). Virtually all elements serve as microbial nutrients. Carbon and nitrogen are macronutrients because so much of the two is needed. Hydrogen and oxygen (for aerobic organisms) are also macronutrients and are obtained through water. Phosphorus, sulfur, calcium, and potassium are required in intermediate amounts. Elements such as iron, copper, magnesium, and cobalt are micronutrients and are needed only in trace amounts.

Production of Sewage Sludge

Once the sewage arrives at the treatment plant it must be thickened and dewatered to form a sludge cake. These sludge cakes are then the material that is composted.

In order to reduce the volume of sludge to be dewatered it is necessary to thicken it. By thickening a 1% sludge to 6% solids the volume of sludge that is handled is reduced by a factor of five (Culp, 1979)(Fig. 1). There are three main methods for sludge thickening: centrifugation, gravity, and flotation.

Centrifugation is the least common method of thickening because of the high cost of the centrifuge itself.

Gravity thickening is the most common concentration process used because it is inexpensive and simple. It is essentially a sedimentation process similar to what occurs in all settling tanks.

In flotation thickening a minute air bubble is attached to the suspended solids and causes the solids to separate from the water. The solids move upward because they now have a lower specific gravity than the water because of the attached air bubble. This sludge blanket is then stripped off the top so it can be dewatered.

There are several different methods for dewatering. They include drying beds, vacuum filtration, centrifugation, pressure filtering, and drying lagoons. Drying beds and drying lagoons are the two most commonly used methods in the U.S.(Villiers, 1977). Drying beds simply consist of sandbeds either in an open field or in an enclosure. After the water drains through the sand the sludge cakes are removed from the beds and then can be sent to the composting facility. At this point the cakes are about 30% solids (Culp, 1979). A drying lagoon consists of a large shallow tank that is filled with thickened sludge. After the majority of the water evaporates the sludge can be sent to the composting facility. The lagoons are usually filled with sludge to a depth of about 40 cm.

COMPOSTING SLUDGE

Controls on Process Temperature

The proper moisture level is essential to maintain microbial activity. If there is a lack of moisture there can be severe rate limitations on the composting process. The moisture level should be as high as possible without saturating the material. If the material becomes saturated then all of the free airspace is removed. Free airspace is important because this maintains aerobic conditions in the composting material. If sludge has not been dewatered enough a bulking agent, such as woodchips, may be added to insure enough free airspace. The woodchips range from 6 to 10 cm in size.

Air must be delivered to the composting material for three reasons. First, air needs to be delivered to satisfy the oxygen demand for the microbes. Second, air needs to be delivered to remove water from very wet materials to provide drying. As air is heated by the composting material, it picks up moisture and thus dries the remaining material. Third, air must be provided to remove heat generated by organic decomposition to control the process temperature. If the process temperature is not controlled it can reach a very high level that would impede biological activity. So the aeration rate can be used to control the rate of heat removed and adjust the temperature of the composting material.

Composting Systems

Composting systems usually fall into three categories: pile, windrow, and bin or enclosed systems. The pile and windrow systems have been used almost exclusively for composting sewage sludge because of their low cost and good performance. The windrow process is better for digested (partially decomposed) sludges. The pile method is better for raw sludge. The bin or enclosed system is becoming a popular method because it is not dependant on the weather.

The composting method is similar for both the windrow and pile methods. The dewatered sludge cakes (about 30% solids) are usually mixed with a bulking agent to increase the porosity so that free airspace can be guaranteed. The usual bulking agent is wood chips but rice hulls and even unscreened finished compost can be used. The normal ratio of sludge to bulking agent is 1:3 (Haug, 1993). The ratio can be varied depending on several factors including moisture content of the sludge cake and the bulking material used. This sludge-bulking material mixture is then formed into windrows or piles. After the composting process is complete the material is cured in large mounds for up to two months. The curing period provides for further pathogen and seed destruction.

Pile Composting

For the pile composting method to work properly a forced ventilation system is required to control the process. The ventilation system maintains proper temperatures and aerobic conditions.

The sewage sludge is not simply dumped into a pile and left to go to work. Rather, about a 30-cm(1-foot) base of bulking agent is built. In this base a perforated pipe is installed for the forced ventilation system (Fig. 2). The dimensions of the base are usually about 12 by 6 m(40 by 20 ft)(Goldstein, 1977). The sludge-bulking agent mixture is then built up to a height of about 2.5 m(8 ft). The pile is then completely covered with a 30-cm(1-ft) thick layer of finished compost to absorb odors and to shield against precipitation. The perforated pipe is attached to a blower. A section of solid pipe goes from the blower to a small pile of screened, finished compost. The gases drawn from the working pile are discharged through the small pile to eliminate odors. The blower runs according to the temperature in the pile. The ideal temperature is between 60-65 degrees Celsius (Inbar, 1990). The normal composting time lasts three weeks. This method is also known as the static pile because it is not turned. This process originated at a USDA facility in Beltsville, Maryland. The Columbus, Ohio facility uses this process.

Windrow Composting

In this method the sludge-bulking agent mixture is formed into windrows that are about 3 to 5-m(10 to 15-ft) wide and 1 to 1.5-m(3 to 5-ft) high (Goldstein, 1977). The cross section of the windrow is triangular(Fig. 3). The windrow is usually turned daily using a composter(Fig. 4). An exception to daily turning is during wet weather. The turning is put off until the surface of the windrow is dry. By turning the material the outer material is moved inward to expose it to the heat needed to destroy pathogens and seeds. The temperature in a windrow ranges from 55 to 65 degrees Celsius. The turning of the windrows also aids in drying and increasing free airspace. The normal composting time for the windrow method is about two weeks but this method is much more dependent on the weather. During wet weather the composting time could reach up to six weeks.

Bin or Enclosed Composting

There are several different types of bin composting systems. The Akron, Ohio facility uses a process known as an aerated agitated bin (Haug, 1993). The equipment at the facility is known as a Paygro System. This system is marketed by Compost Systems Company in South Charleston, Ohio.

The system in Akron has four 60-m(200-ft) wide bays that are 220 m (730 ft) long. Each bay has an operation depth of 3 m(10 ft). Composting time is 3 weeks which is followed by 6 months of static pile curing.

Commercial Applications

Sewage sludge compost has many commercial applications including use on: turfgrass, vegetable crops, field crops, forage grasses, nursery crops, and ornamentals. It also has been used with good results in the reclamation of disturbed lands from coal strip mining and gravel pits.

Sludge compost improves a soil's physical properties by increasing the aeration, increasing water filtration and retention, and by lowering the bulk density. The compost can be used as a fertilizer source or as a soil amendment or conditioner.

Com-Til

The Columbus, Ohio facility markets its sewage sludge compost under the name Com-Til. Com-Til, a mixture of sewage sludge compost and woodchips, is recommended for use as a soil conditioner for potting plants, new lawns, and for trouble area where grass does not grow well.

N-Viro Soil

A Toledo, Ohio company named N-Viro Energy Systems Ltd. uses an EPA approved process to turn sewage sludge to their product, N-Viro Soil, in seven days using a five step system. In step 1 dewatered sludge is combined with N-Viro Alkaline Mixture. In step 2 the material is put into containers. The third step sees the temperature of the material raised to 52 degrees Celsius for 12 hours for the complete destruction of pathogens. During step

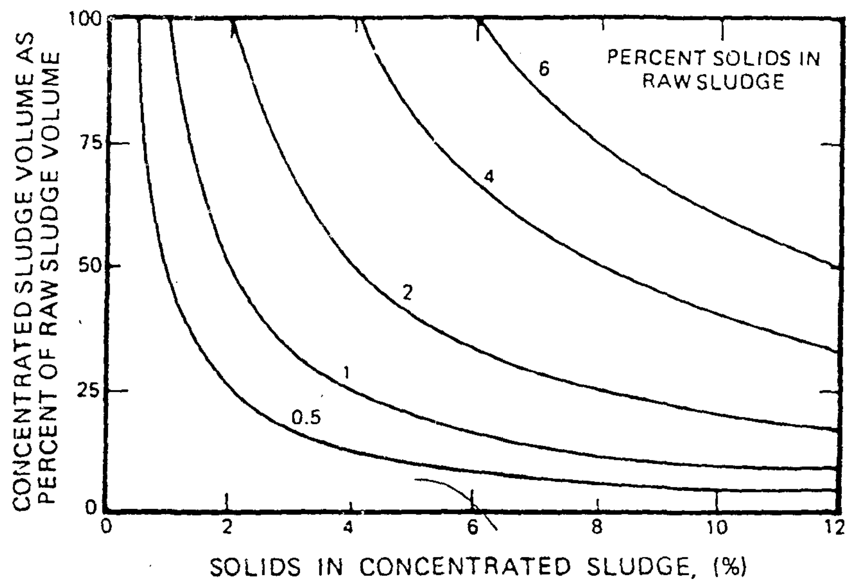
4 the material is windrowed and turned on a drying pad. Step 5 consists of bagging the final pasteurized product.

Heavy Metals

The main problem with composting of sewage sludge is the heavy metals in the sewage. In the Clean Water Act, the U.S. EPA under part 503 established limits on the concentration of arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc (Fig.5). Heavy metals are a problem because they will not leach out of the soil. With repeated applications of sewage sludge compost, these metals may accumulate to levels toxic for both plants and animals. Both Com-Til and N-Viro Soil advertise levels of heavy metals well below the U.S. EPA regulations.

CONCLUDING COMMENTS

The future of sewage sludge composting should be very bright. Composting is a treatment method that is cheaper than land filling or incinerating. It is also better for the environment than other disposal methods and it reclaims useful nutrients. Composting takes a problem waste and naturally converts it to a useful product.



Effects of increasing sludge solids
on the final sludge volume

Figure 1 (From Culp, 1979)

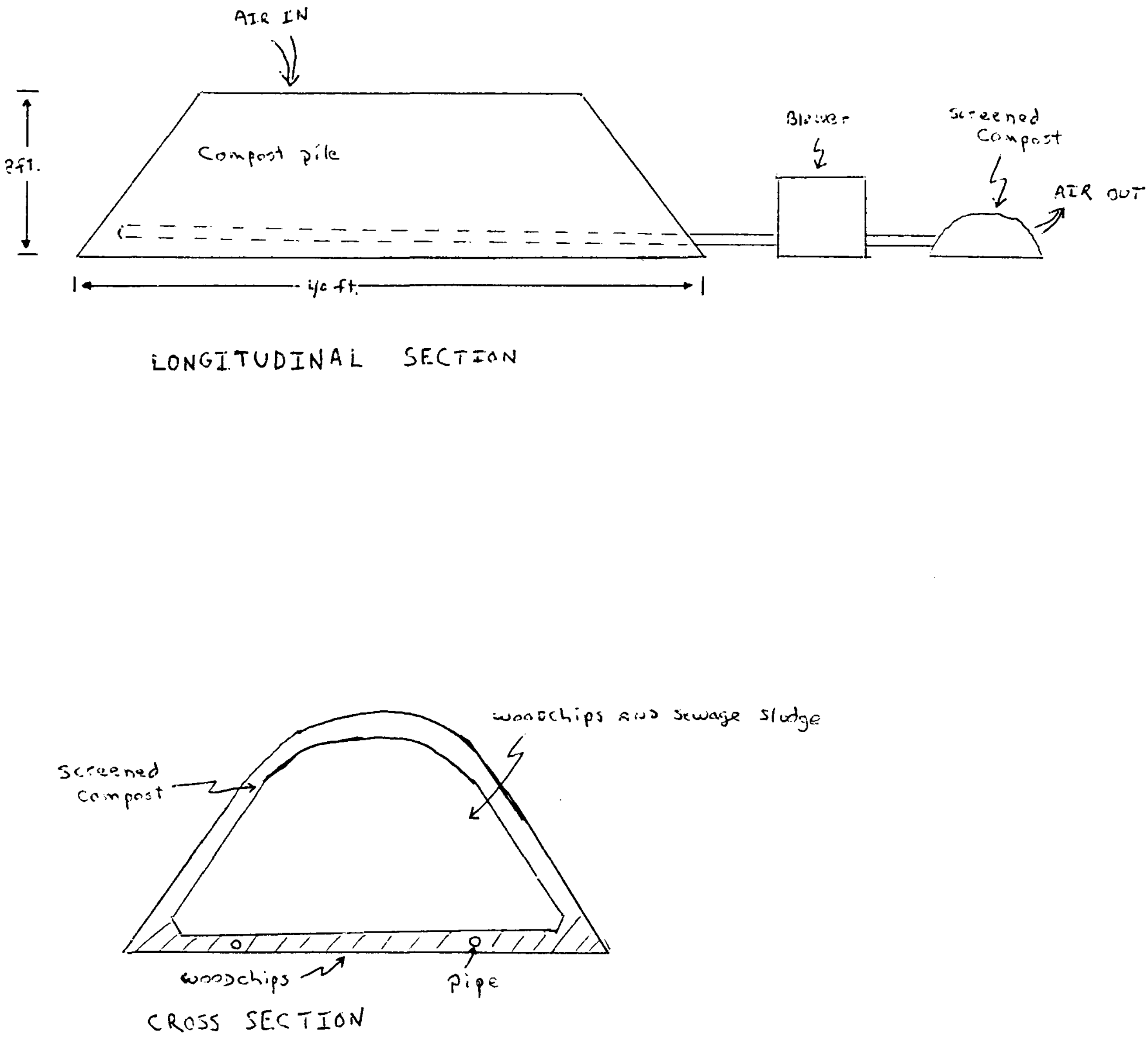


Figure 2 Diagram of static pile (After Culp, 1979)

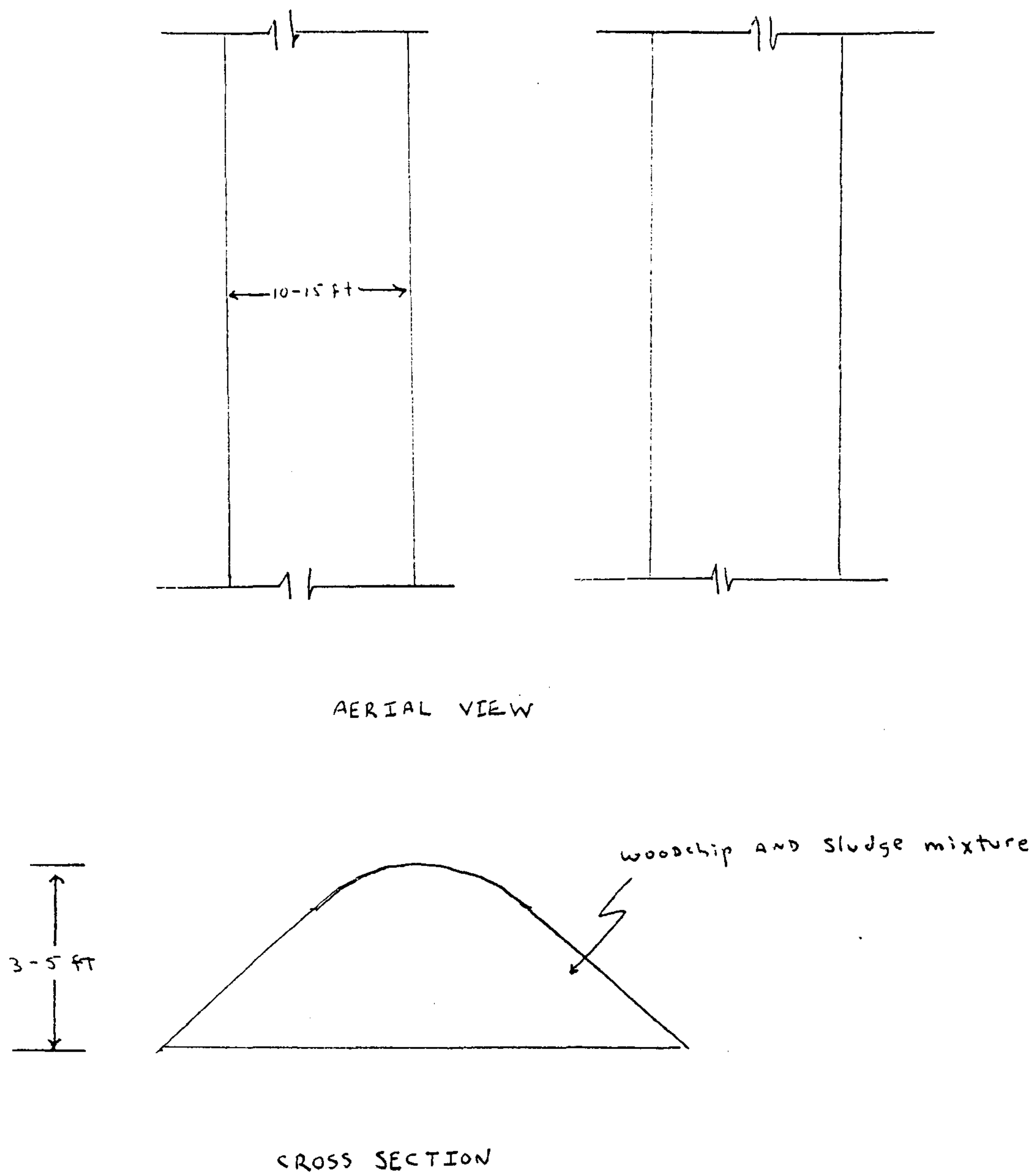


Figure 3 Diagram of windrow

Figure 4 Composter

Clean Water Act[a]

Element	Concentration[b]
Arsenic (As)	41
Cadmium (Cd)	39
Chromium (Cr)	1200
Copper (Cu)	1500
Lead (Pb)	300
Mercury (Hg)	17[c]
Molybdenum (Mo)	18
Nickel (Ni)	420
Selenium (Se)	36
Zinc (Zn)	2800

[a] The U.S. EPA published a final version of this rule in February 1993, but has allowed for additional public comments; therefore, the above values should be used with caution.
[b] Units are mg/kg dry wt.
[c] Valid for all sludge uses except mushroom production.

Figure 5 (From Haug, 1993)

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